COURSE DATA

DATA SUBJECT

Code: 44419
Name: Physical characterisation techniques
Cycle: Master's Degree / Doctorate
ECTS Credits: 4.5
Academic year: 2026-27

STUDY (S)

Degree	Center	Acad. year	Period
2208 - Master's Degree in Molecular Nanoscience and Nanotechnology	Facultat de Química	1	First quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
2208 - Master's Degree in Molecular Nanoscience and Nanotechnology	Physical characterisation techniques	COMPULSORY

COORDINATION

CORONADO MIRALLES EUGENIO

SUMMARY

The aim of this subject is to make the students familiar with physical characterization techniques usually employed in nanoscience (microscopy and spectroscopy), with emphasis on surface sensitive characterization and analysis techniques.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

Previous knowledge of chemistry, physics or materials science as taught in the degrees indicated in the recommended entry profile to the master's degree is required. Previous knowledge of molecular nanoscience and nanotechnology as taught in the Introduction Module is required.

COMPETENCES / LEARNING OUTCOMES

2208 - Master's Degree in Molecular Nanoscience and Nanotechnology

For students from field of knowledge (e.g. chemistry) to be able to scientifically communicate and interact with colleagues from another field (e.g. physics) in the resolution of problems laid out by the Molecular Nanoscience and Nanotechnology.

Students should apply acquired knowledge to solve problems in unfamiliar contexts within their field of study, including multidisciplinary scenarios.

Students should be able to integrate knowledge and address the complexity of making informed judgments based on incomplete or limited information, including reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.

Students should demonstrate self-directed learning skills for continued academic growth.

Students should possess and understand foundational knowledge that enables original thinking and research in the field.

To acquire the basics knowledge in fundamentals, use and applications of microscopic and spectroscopic techniques used in nanotechnology.

To know the technical and conceptual problems laid out by the physical properties measurement in single molecular systems (charge transport, optical properties, magnetic properties).

To possess the necessary knowledge and abilities to continue with future studies in the PhD program in Nanoscience and Nanotechnology.

DESCRIPTION OF CONTENTS

Physical characterization techniques.

CHAPTER 1: Far-field microscopies.
1.1. Introduction
1.2. Optical microscopies
1.2.1. Overview of geometrical optics
1.2.2. Resolution limits and superresolution techniques: Aberrations and diffraction
1.3. Electron microscopies
1.3.1. Fundamentals
1.3.2. Instrumentation: electron sources and electrostatic lenses
1.3.3. TEM, SEM y STEM
1.3.4. Information that can be obtained from the different signals.

CHAPTER 2: Optical spectroscopies.
2.1. Optical properties of nanostructures: quantum confinement, excitons and plasmons.
2.2. Absorption and luminescence spectroscopies: energy gaps and the Frank-Condon principle.
2.3. Infrared and Raman spectroscopies: vibrations

2.4. Pump-probe spectroscopy: Excitation lifetimes.

CHAPTER 3: Photoelectron spectroscopies.
3.1. Photoelectric effect, work function, electron mean-free path and final state effects (screening).
3.2. Instrumentation: Light sources, monochromators, flood guns, energy analyzers
3.3. Instrumentation: Ultra-High Vacuum and sample preparation techniques in UHV
3.4. X-ray Photoelectron Spectroscopy (XPS): Chemical identification and Chemical shifts.
3.5. Ultraviolet Photoelectron Spectroscopy (UPS): Valence band, angle resolved UPS, band dispersion.
3.6. Synchrotron-based techniques: Near-Edge X-ray Absorption Fine Structure (NEXAFS) and magnetic dichroism.
CHAPTER 4: Scanning probe microscopies.
4.1. Scanning Tunneling Microscopy
4.1.1. Theoretical foundations and instrumentation.
4.1.2. Topographical and spectroscopic information with the STM
4.1.3. Inelastic spectroscopy and elementary excitations
4.1.4. STM manipulation
4.2. Atomic Force Microscopy
4.2.1. Theoretical foundations and instrumentation
4.2.2. Topography, friction and Force vs. Distance curves
4.2.3. Mechanical properties of nanostructures
4.3. Other Scanning Probe Microscopies: Magnetic Force Microscopy (MFM) and Scanning Near-field Optical Microscopy (SNOM)

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Tutorials	6,00
Theory	22,00
Seminar	7,00
Other activities	2,00
Total hours	**37,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	0,00
Independent study and work	0,00
Preparation of lessons	18,00
Preparation for assessment activities	57,50
Resolution of case studies	0,00
Total hours	**75,50**

TEACHING METHODOLOGY

The classes of this subject will be taught, together with the rest of the basic module, intensively during 3 weeks in January and each year at a different university.

During the **theory classes**, the teaching staff will give an overview of the subject under study, emphasising new or particularly complex aspects. The necessary bibliographical sources will be indicated for students to study the subject in depth.

The **practical classes** of this subject will be devoted to the organisation of seminars in which problems related to the theoretical content will be posed and solved. Likewise, practical cases and other topics related to the subject will be discussed with the students.

During these hours of practical activities, as far as possible, visits to laboratories and facilities related to the contents of the theoretical classes will be organised. This includes visits to laboratories for advanced physical characterisation of nanomaterials by microscopic (including AFM, STM, TEM and SEM), spectroscopic (including XPS, IR and Raman) and diffraction (including X-ray on single crystal and powder) techniques.

After the intensive face-to-face classes, the lecturers will ask students a series of **questions** about the contents of the course that the student will have to solve.

Professors will hold **tutorials** with the students to resolve any doubts and questions they may have. These tutorials will take place in person or remotely (email, videoconference, telephone, etc.) depending on whether the student and teacher are from the same or a different university.

Through all these activities, students will acquire the competences described in the corresponding section. The basic competences will be worked on above all during the seminars.

EVALUATION

The acquisition of the competences of the subject will be assessed by means of a written exam based on the questions posed to the students. The mark for this exam will represent 90% of the final mark for the subject.

Student participation during the training activities will represent 10% of the final grade.

In order to pass the course, it will be necessary to have attended 80% of the face-to-face training activities.

REFERENCES

- Practical Methods in Electron Microscopy. Ed. Glauer, A.M. Nort Holland Publishing Company. 1990-1997

- Desarrollo de técnicas de espectroscopía láser y su aplicación al análisis químico, Montero Catalina, Carlos, Universidad Complutense de Madrid, Servicio de Publicaciones, 2001
- Introduction to Scanning Tunneling Microscopy. Chen, C.J. Oxford Scholarship Online. 2007.